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ANOMALOUS ANTICIPATORY EVENT-RELATED EEG ACTIVITY IN A FACE RECOGNITION MEMORY TASK

Marios Kittenis

Psychology, School of Life and Health Sciences

Aston University, Birmingham

Anomalous anticipatory effects in baseline psychophysiological measures recorded in studies not intending to investigate psi phenomena have been reported before (e.g. Bierman, 2000). We report another instance of apparently anomalous anticipatory activity identified in EEG data recorded as part of a study investigating ordinary parameters of mood and face recognition memory (Burgess et al., unpublished). Twenty-eight channels of EEG were recorded from ten healthy controls and ten patients with bipolar disorder, while they were first exposed to an experimental mood induction procedure and then performed a face recognition memory task. Neutral and sad mood was induced (in counter-balanced order) by asking participants to recollect autobiographical memories of sad or emotionally neutral events, and participants were then asked to discriminate between unfamiliar (new) and familiar (old) faces presented in a randomised order on screen.

The method of Empirical Mode Decomposition (EMD) was used to analyse the EEG data. This is a data-driven approach to signal analysis which can be used to decompose a complex (i.e. broad-band) signal into simpler component signals of narrow frequency bandwidth. For EEG data these decomposed signals (called 'Intrinsic Mode Functions' or IMFs) correspond approximately to the traditional EEG frequency bands; EMD however does not require pre-specifying the frequency bands expected in the signal, as these are derived empirically from the raw EEG through a simple iterative process. EMD does not assume linearity or stationarity properties in the signal, and has been shown to outperform other methods of time-frequency analysis in estimating the instantaneous (i.e. time-variant) amplitude and frequency of the signal, as well as its instantaneous phase synchronisation (Sweeny-Reed et al., 2007).

Using EMD, four parameters of event-related EEG activity were estimated: evoked (i.e. phase-locked) amplitude, induced (non-phase-locked) amplitude, instantaneous frequency, and phase synchronisation. For each of these four variables, Partial Least Squares (PLS) analysis was performed to identify potential differences in EEG activity between neutral and sad induced mood, and between responses to new and old faces (i.e. face recognition task). PLS is a combination and extension of multiple regression and Principal Components Analysis, and for EEG data it is used to test whether there is a significant effect due to the experimental manipulation, as well as the temporal and spatial (i.e. scalp) location of the effect. PLS identifies latent components and tests their significance without restricting analysis to predetermined scalp areas or times of interest, and uses all the data in the time series while controlling for Type-1 error.

Expected effects of mood induction and face recognition were identified in induced amplitude, evoked amplitude and phase synchronisation measures in certain frequency bands (IMFs), and the temporal and spatial (scalp) location of these effects was explored. In the course of this analysis an unexpected effect was also identified during the pre-stimulus period, in the form of a significant difference in measures of phase synchronisation between New and Old faces. This effect was found in IMF5 ($p < 0.001$), IMF4 ($p < 0.000$) and IMF3 ($p < 0.000$), which correspond to frequency bands of 3-6Hz, 6-12Hz, and 12-22Hz respectively (i.e. closely matching the theta, alpha, and beta1 bands respectively). The effect was observed within the one-second period prior to stimulus onset, and was fairly widely distributed across electrode locations. As the order of presentation of New and Old faces was pseudo-randomly determined in each trial, it is difficult to account for differences in brain activity prior to stimulus presentation by any known neurophysiological process.

Further investigation of this effect was undertaken to rule out possible artefacts. Linear filtering can distort the timing of event-related EEG components both forwards and backwards in time, depending on the direction of filtering. Low-pass filtering was not used in this study, as the EMD process itself successively extracts high frequency noise in the first few IMFs without distorting the timing of EEG components. High-pass filtering (0.5Hz) was used to remove slow potential drift, although a 'zero phase-shift' filter was used which filters both forwards and backwards in time to cancel out any phase distortion.

A more likely source of error was later identified when consistently smaller numbers of epochs were found to be associated with New compared to Old stimuli; this discrepancy may bias comparisons of epoch average measures, as disproportionately greater residual noise would be expected in an average of fewer epochs. Therefore the dataset was re-analysed with an equal number of epochs randomly sampled from each condition to ensure an equalised epoch-count for New and Old stimuli. When the same analysis as described above (EMD followed by PLS) was performed on this epoch-equalised dataset, the effect was no longer found. However, this may simply reflect the poorer signal-to-noise ratio in the equalised sample, as in order to equalise epoch-counts between conditions we necessarily had to discard a considerable number of epochs (approximately one third of the data). The fact that the main (post-stimulus) effects of mood induction and new/old face recognition were also absent in this equalised dataset supports this view. Baseline correction after averaging is another way to control for unequal numbers of epochs (although it is difficult to choose an appropriate baseline period for a pre-stimulus effect); using the period between -2000 to -1500ms as a baseline the pre-stimulus difference between new/old conditions remained significant, which points against the possibility that baseline problems are involved.

The only remaining possibility for an artefact we can identify is poor randomisation of the stimuli, which may have enabled participants to unconsciously identify a bias in their presentation order and thus produce differential anticipatory responses for New versus Old faces. We consider this unlikely, although we must accept it as a possibility especially as we have not been able to establish whether randomisation with replacement was used (as relevant documentation has not been retained by the experimenters). As Bierman (2000) points out, the presence of this effect implies that the common practice in psychophysiological research of using the period just prior to stimulus presentation as a baseline may introduce bias in estimates of post-stimulus main effects. In our dataset, using the pre-stimulus period as the baseline often rendered the main post-stimulus effects non-significant. For this reason, this effect deserves careful study regardless of its nature, as it carries practical implications for psychophysiological research.

Over the past year we have been collecting data for another study with a similar design to the one presented here, which uses a high-density electrode montage (128 channels) and a protocol involving randomised inter-stimulus intervals and stimulus randomisation with replacement. As this experiment was also designed to study face recognition memory and not to investigate potential psi effects, we consider it as an unintended opportunity to examine this effect further.